Environmental Factors in Cancer: Radon

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CURRENT UNDERSTANDING
Radon –222 (radon)

- Radon is a gas
- It is naturally occurring outdoors
- In general - the primary source of radon is from the soil
- In most cases, builders do not choose to build homes radon resistant
Radon Decay Products (RDPs)

- Radon enters home
- Radon decays into RDPs in the air
- Some RDPs remain in the air
- Some RDPs plate out on surfaces
Radon Decay Products

$^{218}\text{Po}$ and $^{214}\text{Po}$ deliver the radiologically significant dose to the respiratory epithelium.

- Radon-222
  - $\alpha,\gamma$
  - 4 day
- Polonium-218
  - $\alpha,\gamma$
  - 3 min
- Lead-214
  - $\beta,\gamma$
  - 27 min
- Bismuth-214
  - $\beta,\gamma$
  - 20 min
- Polonium-214
  - $\alpha,\gamma$
  - 0.2 ms
- Lead-210
  - $\beta,\gamma$
  - 22 yrs
- Bismuth-210
  - $\beta,\gamma$
  - 5 day
- Polonium-210
  - $\alpha,\gamma$
  - 138 day
- Lead-206
  - Stable
What happens when radon decay products are inhaled?

- Highly radioactive particles adhere to lung tissue, where they can irradiate sensitive cells.
- Radiation can alter the cells, increasing the potential for cancer.
Radon causes lung cancer even below the U.S. EPA’s radon action level of 150Bq/m$^3$ (4 pCi/L)

<table>
<thead>
<tr>
<th>Residential Epidemiologic Study</th>
<th># of studies pooled</th>
<th># of lung cancer cases/controls</th>
<th>Increased risk per 100 Bq/m$^3$ (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North American Pooled Analysis</td>
<td>7</td>
<td>3,662/4,966</td>
<td>11% (0% - 28%)</td>
</tr>
<tr>
<td>European Pooled Analysis</td>
<td>13</td>
<td>7,148/14,208</td>
<td>8% (3% - 16%)</td>
</tr>
<tr>
<td>Chinese Pooled Analysis</td>
<td>2</td>
<td>1,050/1,995</td>
<td>13% (1% - 36%)</td>
</tr>
</tbody>
</table>
Pooled risk estimates likely underestimate the true risk posed by protracted radon exposure

1. Errors in radon detector measurement

2. Failure to consider temporal and spatial radon variations within a home

3. Missing information on radon exposure from other sites, such as prior homes

4. Failure to properly link radon concentrations with subject mobility

5. Measuring radon gas as a surrogate for radon progeny exposure
Risk estimates increase with improved exposure assessment

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<th>Residential Epidemiologic Study</th>
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<th>Increased risk at 100 Bq/m$^3$ Analyses based on improved radon concentration data (95% CI)</th>
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<td>North American Pooled Analysis</td>
<td>11% (0% - 28%)</td>
<td>18% (2% - 43%)</td>
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Analysis restricted to individuals who resided in either one or two homes for the period 5 to 30 years prior to recruitment and also had at least 20 years covered by a year-long radon measurement.
Iowa Radon Lung Cancer Study (IRLCS)

- The NIEHS\NCI funded IRLCS collected historical information on participant mobility within the home, time spent outside the home, and time spent in other buildings.
- Numerous yearlong radon measurements were performed on each level of the participant's home.
- Outdoor radon measurements were also conducted in addition to workplace radon exposure assessments.
- The spatially diverse measurements were linked to where the participant spent time, for at least the proceeding 20 years, in order to obtain a cumulative radon exposure for the individual.

IOWA RADON LUNG CANCER STUDY

EXPOSURE CATEGORIES

ODDS RATIO

Iowa Comprehensive Exposure Model
Living Area and Bedroom Concentration
Most radon-induced lung cancers occur below the U.S. EPA’s radon action level

Zone 1 - Predicted average indoor screening level > than 4 pCi/L
Zone 2 - Predicted average indoor screening level between 2 and 4 pCi/L
Zone 3 - Predicted average indoor screening level less than 2 pCi/L
Protracted radon exposure increases the risk of all types of lung cancer

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<th>Residential Study</th>
<th>Histologic type most associated with radon exposure</th>
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<td>Small Cell</td>
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<td>Iowa Radon Lung Cancer Study</td>
<td>Large Cell Squamous</td>
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<td>CANCER TYPE</td>
<td>ESTIMATED U.S. DEATHS/YR</td>
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Radon is one of our major environmental toxicants in the United States

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Mitigation and Radon Resistant New Construction (RRNC) methods are available to reduce the risk.

For example, a recent study reported that the pre-mitigation radon concentrations in a survey of 166 homes averaged 380 Bq/m$^3$ (10.3 pCi/L), while post mitigation radon concentrations averaged 44 Bq/m$^3$ (1.2 pCi/L).

Individual susceptibility to radon-induced lung cancer

- Smokers and ex-smokers
- Individuals with lower socioeconomic status
- Infants and Children
- Individuals who have mixed exposures to lung carcinogens
- Individuals who have a history of medically-related radiation exposure (x-ray therapy, etc.)
- Variation by genotype
Ionizing radiation can directly and indirectly damage DNA

Alpha Particle

Defects in tumor suppressor genes – p53

At risk individuals–GSTM$_1$

(glutathione S-transferase M1)
Adverse health outcomes related to protracted radon exposure other than lung cancer

**Miner-based epidemiologic studies**

Suggestive evidence for stomach cancer, liver cancer, skin cancer, and leukemia

**Recent miner-based incidence study of leukemia**

Incidence of all leukemia combined as well as chronic lymphocytic leukemia (CLL) was positively associated with cumulative radon exposure

Non-statistically significant increases were also noted for myeloid leukemia and Hodgkin’s lymphoma

Radiation Exposure and Leukemia

A recent methodologically advanced study in Iowa using the Iowa SEER cancer registry also noted an increased risk for CLL, and CML, at the geographic level.

Several other recent studies have also suggested a potential association with radiation exposure and CLL. Until recently, CLL was the only subtype of leukemia not thought to be radiogenic.

Smith et al. (2007); Linet et al. (2007)
RESEARCH NEEDS
Epidemiologic Studies

1. Assess risk factors affecting individual susceptibility (e.g., genetic polymorphisms) to radon-induced lung cancer

2. Assess the possible associations between radon exposure and extrapulmonary cancers (e.g., leukemia, lymphoma, chronic myeloid neoplasms, stomach, melanoma, etc.)
Radon could be included as an exposure of interest under future funding for understudied rare cancers.
Cost effectively include radon exposure assessment as a component of on-going prospective cohort studies.
A radon decay product retrospective detector has been recently calibrated with NCI for use in epidemiologic studies.

- Glass-based radon progeny measurement
- Measures contemporary radon gas concentration
- Measures contemporary radon progeny deposition
- Measures retrospective deposition of radon decay products in glass surfaces via implanted $^{210}\text{Po}$
Nationwide assessment of workplace exposures warranted

- Mine workers, including uranium, hard rock, and vanadium
- Workers remediating radioactive contaminated sites, including uranium mill sites and mill tailings
- Workers at underground nuclear waste repositories
- Radon mitigation contractors and testers
- Employees of natural caves
- Phosphate fertilizer plant workers
- Oil refinery workers
- Utility tunnel workers
• Subway tunnel workers
• Construction excavators
• Power plant workers, including geothermal power and coal
• Employees of radon health mines
• Employees of radon balneotherapy spas (waterborne radon source)
• Water plant operators (waterborne radon source)
• Fish hatchery attendants (waterborne radon source)
• Employees who come in contact with technologically enhanced sources of naturally occurring radioactive materials
• Incidental exposure in almost any occupation from local geologic radon sources
• Agricultural exposures
POLICY

• The U.S. EPA deserves significant credit for their tremendous leadership over the past 20 years to reduce radon exposure on many fronts.

• Nonetheless, we are loosing the battle against reducing an individual’s exposure to radon.

• The adverse health effects from radon will increase as more people are exposed, with the aging of our population, and with increased medically-related radiation exposure.
From 2008 Office of Inspector General Report – total of number of homes built in high radon areas compared to number of homes constructed with radon resistant features.

- New homes built with RRNC in Zone 1 is based on EPA’s estimate that 60 percent of all homes built with RRNC are in Zone 1.
Number of single family homes and number with radon reduction features

Source: OIG analysis of U.S. Census Bureau data on homes and gross annual radon fan sales data supplied by fan manufacturers to EPA’s Indoor Radon Team.
Policy Considerations

- Among other recommendations, the U.S. EPA’s Office of Inspector General strongly recommended that the U.S. EPA consider using their authority, including legislation, already provided under the 1988 Indoor Radon Abatement Act (IRAA) to reduce the risk posed by protracted radon exposure.

- Numerous cost/benefit analyses have clearly indicated that both mitigation of existing homes and adopting radon resistant new construction features can be justified on a national level (WHO 2008, Steck 2008).

- In order to reduce the number of radon-related lung cancers by half, the current EPA action level for radon may need revisited.
In memory of -

David S. Chase

Manager of the Radon Program for the state of New Hampshire, Department of Environmental Services
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